Geol 335.3

Lab #6: Common mid-point method

In this lab, you will study the principle of the common-midpoint (CMP) reflection method by making simple Matlab or Octave simulations. Tools and functions from the previous labs will be useful in this exercise.

Theory

Unlike the common-shot seismic data studied in the previous lab, CMP records are collected by moving both sources and receivers in opposite directions so that their midpoint remains constant while the source-receiver distance increases. CMP gathers are usually presented in the form of time-offset seismic sections.

The primary use of CMP gathers is for *stacking velocity analysis*. There exist many ways to calculate the “semblance” function, which is used to determine the optimal values of stacking velocity V at variable reflection times t_0. In its simplest form, velocity analysis is performed by trying a set of and for each of them, stacking the energy along the reflection hyperbola:

$$Semblance(t_0,V)=\frac{1}{N}\sum_{i=1}^{N}u_i^2\left(\sqrt{t_0^2+\left(\frac{x_i}{V}\right)^2}\right) \quad , \qquad (1)$$

where $u_i(t)$ is the signal it i^{th} channel, and x_i is the source-receiver offset at its location. However, in this lab, we use a different measure that provides smoother peaks:

$$Semblance(t_0,V)=const\times smooth\left\{\left[\sum_{i=1}^{N}u_i\left(\sqrt{t_0^2+\left(\frac{x_i}{V}\right)^2}\right)\right]^2\right\}, \qquad (2)$$

i.e. smoothed squared stack of the waveforms evaluated along the reflection hyperbola.

For a horizontal reflector, the stacking velocity equals the averaged (in the sense discussed in class) velocity above it. When reflector dip α is present, the stacking velocity increases:

$$V_{\text{with dip}}=\frac{V_{\text{no dip}}}{\cos\alpha}. \qquad (3)$$

Code

In another copy of your `model1.m` file (from lab 5), rename `sources` to `midpoints`. For each midpoint number `n`, you can obtain a CMP section by using a small modification of function `reflection(…)` called `reflection_CMP(…)`. In this function, source positions are variable for each receiver, so that <u>the midpoint is fixed</u>. For example, for the first midpoint (denoted `midpoints(1)` in your code), the resulting section will be produced by

```
sec = reflection_CMP(midpoints(1),receivers,layer,2.0);
```
(4)

To plot this section, you will need to first calculate the relative source-receiver distances (verify that this formula is correct!):

```
offsets(1,:) = 2*(receivers - midpoints(1))
```
(5)

Then, the plot is obtained by:

```
plot_section(offsets(1,:),sec,'Offset (m)','b-')
```

To compute the velocity spectra in eq. (2), we provide function `semblance()`. Look into its code. Note that it is constructed very similarly to `reflection()`, by first initializing a blank semblance and then adding to it contributions from all traces using `interp1()`. The output of `semblance()` also represents a trace section, which can be plotted by `plot_section()`:

```
plot_section(V, sec,'V(km/s)','b-'),
```

where `V` is the array of trial stacking velocities.

Assignments

Following the instructions in `model1.m`, do the following:

1. [10%] Put three points (or more if you like) into array `midpoints`. Complete the `for` loop in the code to calculate the source-receiver offsets by formula (5) above.
2. [10%] Execute the modified script `model1.m` and pick three horizontal reflecting boundaries. To pick any boundary, click at two points and then press spacebar. Place the first boundary `layer1` in the bottom half of the section, and `layer2` and `layer3` above it.

After you have picked the boundaries, you can comment out the interactive out and uncomment the 'load' command. This will re-load your picked boundaries next time you run the script.

3. [20%] For one midpoint near the middle of the line, generate reflection sections (by using `reflection_CMP()`) with different velocities. Try several values of velocity to see how they affect the shapes of reflections.

Note that the relative variations of velocity should be smaller than those of layer depths, so that the reflection travel times would decrease from `layer1` to `layer 3`. For example, if layer depths are related as 1:2:3 in your model, then velocities could be related as 1:1.5:2. In eq. (4) above, you can then create a record section named `sec1` using velocity $V = 2$ km/s for the deepest `layer1`, then make section `sec2` using $V = 1.5$ km/s for `layer2`, and `sec3` using $V = 1$ km/s for `layer3`.

After modeling `sec`, `sec2`, and `sec3`, sum these three sections together:

`section = sec + sec2 + sec3`

This summation should illustrate how reflections from different depths overlap in real seismic data.

Note how the times of reflections at zero source-receiver offsets (t_0) correspond to the depths of reflectors, and the moveouts (slopes) of reflection hyperbolas correspond to the lower or higher velocities.

The resulting section will be saved in `model1.mat` file, and the following velocity analysis steps you can do in a separate script `model2.m.` This script will not have to re-compute the synthetics and will run quicker.

4. [10%] In script `model2.m`, compete the call to `semblance()`, which uses the the CMP gather `section` to compute and plot the velocity spectrum (eq. 2) for stacking velocities `v=0.7:0.05:2.5 m/ms` (note that these units are the same as km/s).
5. [10%] Determine whether the velocities and t_0 set for the three reflectors are correctly determined by the peaks in velocity spectrum. From the plots, describe the velocity resolution (width of velocity peaks) varies with t_0 and velocity.
6. [20%] Run `model1.m` again and pick two points to make a dipping reflecting boundary close to the depth of the middle reflector in the preceding test. Plot the common-midpoint gather. How does it differ from the horizontal-reflector case? Is it shifted up-dip or down-dip (or not shifted)? What happens if the dip is changed?
7. [10%] Plot the velocity spectrum for the dipping interface case. How do the optimal stacking velocity change? Why? Compare the result to the prediction from formula (2).
8. [10%] Try summarizing the differences of the horizontal and dipping reflector cases.

Hand in:

Zipped directories containing:

1. All Matlab codes (“m-files”);
2. Screen captures or Postscript/PDF figures;
3. Discussion in a Word file.